

4500
FS-2-e4-6

Portland, Oregon
May 1, 1960

INTERMOUNTAIN STATION
Central Reference File

No. 3.4192

PROGRESS REPORT

FOREIGN PREDATOR INTRODUCTIONS FOR CONTROL OF THE
BALSAM WOOLLY APHID IN THE PACIFIC NORTHWEST
1957-1960

By
P. E. Buffam, Entomologist
and
R. G. Mitchell, Entomologist

FOREST SERVICE
INTERMOUNTAIN
RECEIVED

JUN 7-'61

FOREST INSECT LAB.
MISSOULA, MONT.

NOT FOR PUBLICATION

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

FILE COPY

MISSOULA
FOREST INSECT
LABORATORY

SUMMARY

For the fourth consecutive year, foreign insect predators were introduced in Oregon and Washington for control of the balsam woolly aphid, Chermes piceae Ratz. Nine species of lady-bird beetles, totaling 7,461 specimens, were released in 1960. This brings the total number of predators liberated in the Pacific Northwest since 1957 to 18 species and some 60,000 specimens.

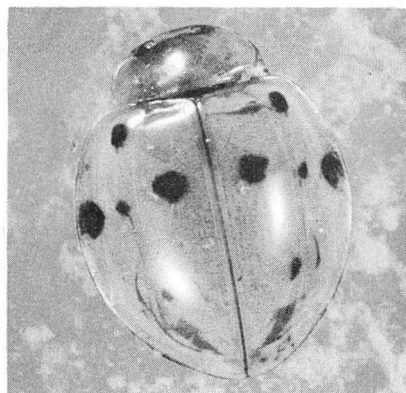
Of the nine coccinellid species received in 1960, one came from Germany, one from Australia, and the other seven from the southern Himalaya Mountains of India and Pakistan. Himalayan predators were collected or reared by native entomologists working for the Commonwealth Institute of Biological Control at laboratories in Bangalore, India, or Rawalpindi, Pakistan. Services of CIBC were contracted by the U. S. International Cooperation Administration under authority vested by Public Law 480, U. S. Agricultural Trade Development and Assistance Act of 1954. European and Australian predators were sent through the cooperation of the Canada Department of Agriculture, which also contracts with CIBC.

The predators received in 1960 were released both in the field and in laboratory cages. Attempts at laboratory rearing were generally unsuccessful. The results of field liberations have not been determined.

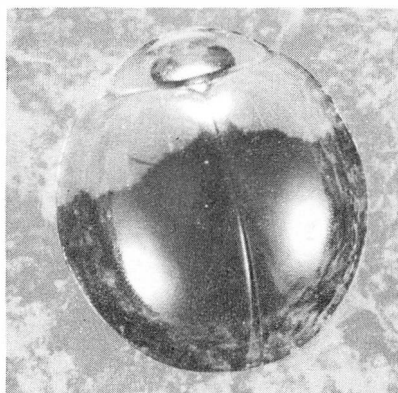
Four of 14 predator species introduced from 1957 through 1959 are established. All were European imports: Laricobius erichsonii Rosen., Aphidoletes thompsonii Mohn., Cremifania nigrocellulata Cz., and Leucopis obscura (Hal.). The most promising predator was L. erichsonii. Investigations during 1959 and 1960 revealed that Laricobius delivered significant predation in several release areas. Control benefits of the other three established predators have not been quantitatively evaluated.

As far as is known, the remaining 10 species introduced from 1957 through 1959 did not survive. Only one of these species, the European beetle predator, Aphidecta oblitterata L., completed a generation; it produced progeny the summer it was released but later disappeared.

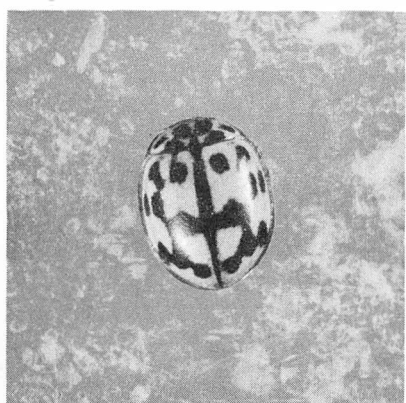
As in the past, Weyerhaeuser Company cooperated in the introduction program by selecting release sites and liberating predators. The program was also aided by continued cooperation with Oregon State University.



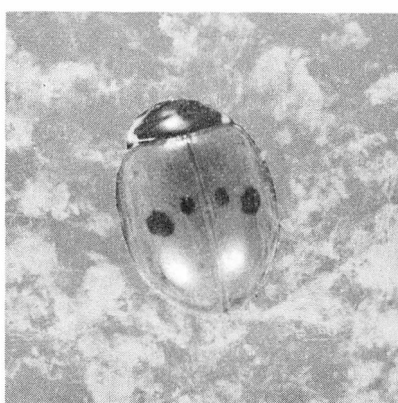
Ballia eucharis



Leis dimidiata



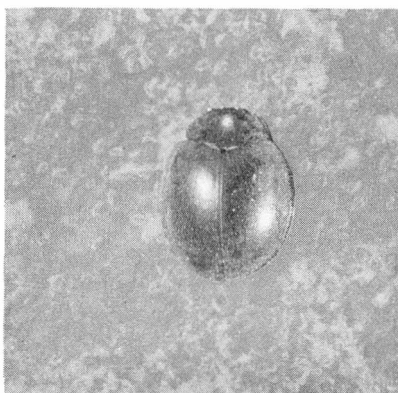
Synharmonia conglobata



Adalia tetraspilota



Oenopia sauseti



Exochomus uropygialis

LADYBIRD PREDATORS FROM INDIA AND PAKISTAN

TABLE OF CONTENTS

| | <u>Page</u> |
|---|-------------|
| SUMMARY | |
| INTRODUCTION | 1 |
| ARRANGEMENTS FOR PREDATOR INTRODUCTIONS | 1 |
| COLONIZATION PROGRAM IN 1960 | 2 |
| Introduction and Liberation | 4 |
| Release Results | 5 |
| STATUS OF PREDATORS RELEASED FROM 1957 THROUGH 1960 | 5 |
| Established Predators | 6 |
| <u>Laricobius erichsonii</u> | 6 |
| <u>Aphidoletes thompsoni</u> | 9 |
| <u>Cremifania nigrocellulata</u> | 10 |
| <u>Leucopis obscura</u> | 10 |
| Other Predators | 11 |
| <u>Adalia luteopicta</u> | 11 |
| <u>Adalia tetraspilota</u> var. <u>bispilota</u> | 11 |
| <u>Aphidecta oblitterata</u> | 11 |
| <u>Ballia eucharis</u> | 12 |
| <u>Chilocorus kuwanae</u> | 12 |
| <u>Exochomus uropygialis</u> | 12 |
| <u>Exochomus uropygialis</u> var. <u>lituratus</u> | 12 |
| <u>Harmonia breiti</u> | 12 |
| <u>Leis dimidiata</u> | 13 |
| <u>Leucopis (Neoleucopis) sp.</u> | 13 |
| <u>Oenopia sauseti</u> | 13 |
| <u>Pullus impexus</u> | 13 |
| <u>Scymnus pumilio</u> | 13 |
| <u>Synharmonia (Coccinella) conglobata</u> | 14 |
| PROJECT PERSONNEL | 14 |
| APPENDIX | 15 |

LIST OF ILLUSTRATIONS AND TABLES

| | <u>Page</u> |
|--|-------------|
| Frontispiece - Ladybird predators from India and Pakistan . . . | |
| Figure 1. Location of release areas in Oregon and Washington used for liberating foreign predators of the balsam woolly aphid from 1957 through 1960 (map) | Appendix |
| Table 1. Summary of 1960 field and laboratory releases in Oregon and Washington | 3 |
| Table 2. Foreign insect predators introduced since 1957 for control of the balsam woolly aphid in Oregon and Washington | 7 |
| Table 3. Shipments and colonizations of foreign predators of the balsam woolly aphid in 1960 | Appendix |
| Table 4. Releases of foreign predators of the balsam woolly aphid in Oregon and Washington from 1957 through 1960 by species | Appendix |

FOREIGN PREDATOR INTRODUCTIONS FOR CONTROL OF THE
BALSAM WOOLLY APHID IN THE PACIFIC NORTHWEST
1957-1960

By
P. E. Buffam and R. G. Mitchell

INTRODUCTION

Since 1957, 18 species of foreign insect predators, representing some 60,000 specimens, have been introduced into the Pacific Northwest for the control of the balsam woolly aphid, *Chermes* (=Adelges) *piceae* Ratz. This report describes: (1) Arrangements for introducing the predators, (2) the methods and results of the 1960 introductions, and (3) status of the colonization attempts made from 1957 through 1960. Methods and procedures of past liberations have been reported. 1/ 2/ 3/

ARRANGEMENTS FOR PREDATOR INTRODUCTIONS

Predators liberated in Oregon and Washington since 1957 have been collected from nations in several parts of the world: five species from Sweden, Germany, and Czechoslovakia in Europe; eleven species from Pakistan, India, and Japan in Asia; one species from Australia; and one species from eastern United States. The first predators introduced in this region were made available to the Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, through a cooperative agreement initiated in 1957 between the Canadian and United States Department of Agriculture. Later, in 1960, an agency of the U. S. Department of State added its support and financing to the predator collection and introduction program.

1/ Wright, K. H. and R. G. Mitchell. Progress Report: Colonization in Oregon and Washington of *Aphidoletes thompsoni* - An European Predator of the Balsam Woolly Aphid. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. Feb. 1, 1958.

2/ Wright, K. H., P. E. Buffam, and R. G. Mitchell. Progress Report: Colonization of Foreign Insect Predators in 1958 for Control of the Balsam Woolly Aphid. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. March 15, 1959.

3/ Buffam, P. E., K. H. Wright, and R. G. Mitchell. Progress Report: Predator Introductions in 1959 for Control of the Balsam Woolly Aphid and an Evaluation of Releases to Date. Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. March 15, 1960.

Predators received during the first three years of the agreement were largely supplied by the Canadian government. They were collected in foreign countries, chiefly in western Europe and Australia, and shipped to North America through a Canadian-financed program with the Commonwealth Institute of Biological Control (CIBC). The Entomology Research Institute of Biological Control in Belleville, Ontario, then screened the shipments and transmitted part of them to the Pacific Northwest. Predators retained by the Canadians were used in their own biological control program against Chermes piceae in the Maritime Provinces and in British Columbia.

The first significant contribution by the United States to the predator introduction program was made in 1958. A representative of the U. S. Forest Service was sent to Japan to explore predator collection possibilities, the predators to be used by both Canada and the United States. In 1960, the contribution was expanded further when the International Cooperation Administration (ICA), U. S. Department of State, contracted with CIBC to collect chermid predators in India and Pakistan. Funds for this project were made available under terms authorized by subsection 104(k), Public Law 480, U. S. Agricultural Trade Development and Assistance Act of 1954. Most of the predators sent to the Pacific Northwest in 1960 were made available through the above ICA contract.

COLONIZATION PROGRAM IN 1960

Nine species of foreign insect predators were sent to the Pacific Northwest in 1960 for control of the balsam woolly aphid. All were coccinellids in the adult stage. Two of the species were routed to Portland, Oregon, from Australia and Germany by the Canada Department of Agriculture. The other seven were sent from India and Pakistan through the auspices of the International Cooperation Administration. Table 1 shows the source of each predator species and the number introduced in 1960.

Table 1.--Summary of 1960 field and laboratory releases
in Oregon and Washington ^{1/}

| Species | : Source | : No.field-: : released | : No.lab.-: : released | : Total |
|--|-----------|----------------------------|---------------------------|---------|
| <u>Adalia</u> <u>luteopicta</u> Muls. | India | 20 | 136 | 156 |
| <u>Adalia</u> <u>tetraspilota</u> Hope var. <u>bispilota</u> Wse. | India | | 12 | 12 |
| <u>Exochomus</u> <u>uropygialis</u> Muls. | Pakistan | 4425 | 300 | 4725 |
| <u>Exochomus</u> <u>uropygialis</u> var. <u>lituratus</u> Gorh. | Pakistan | 43 | | 43 |
| <u>Harmonia</u> <u>breiti</u> Mader | Pakistan | | 73 | 73 |
| <u>Oenopia</u> <u>sauseti</u> Muls. | India | | 46 | 46 |
| <u>Pullus</u> <u>impexus</u> Muls. | Germany | 400 | | 400 |
| <u>Scymnus</u> <u>pumilio</u> (Wse.) | Australia | 2000 | | 2000 |
| <u>Synharmonia</u> (Coccinella) <u>conglobata</u> L. | India | | 6 | 6 |
| Total | | 6888 | 573 | 7461 |

^{1/} All species are in the family Coccinellidae.

Introduction and Liberation

As in the past, predators were shipped by air from overseas collection sites to forwarding laboratories in Canada and the United States. These laboratories screened the insects for parasites and other undesirable organisms and then routed them to final destinations for field release. Specimens supplied by the Canadians were screened at Belleville, Ontario, and then relayed by air express to Portland in the usual CIBC wooden containers.^{4/} Insects from the ICA projects were collected in the southern Himalaya Mountains and sent to the Agricultural Research Service laboratory at Moorestown, New Jersey. From there they were shipped to Portland by air mail in pint ice-cream containers packed in cardboard boxes. Time in transit from screening laboratories to Portland varied from 24 to 36 hours. Insect mortality during transit ranged from 0 to 33 percent.

Not all predators received in 1960 were released in the field. Four species were retained in the laboratory for cage studies. Two other species were separated into lots, some being held in the laboratory and some being field-released. All specimens of the remaining three species were liberated in the field. Table 1 shows the species that were field-released and those retained in the laboratory. Table 3 in the Appendix shows the release location of each shipment.

Predators withheld from field-release were placed in 24x24x33-inch cages in the laboratory at Portland. Each cage was set on damp vermiculite and supplied with a fresh, aphid-infested subalpine fir log. Sealing the severed ends of the infested logs with hot paraffin assured a living host supply for about 3 weeks. Supplemental food in the form of cubed sugar and powdered milk was also supplied the beetles. A vial of water inverted on a blotter furnished moisture. Temperature in the rearing rooms varied from 70° to 80° F. throughout the summer. Relative humidity was generally high, ranging from 50 to 70 percent.

Field liberation procedures followed those of previous years. Release areas were selected on the basis of: (1) access, (2) presence of suitable host supply, (3) probable duration of the infestation, and (4) proximity to previous release sites. All field liberations were "free"; that is, without confining the insects in cages. *Adalia luteopicta* Muls. and *E. uropygialis* var. *litratus* Gorb. were released in stands of chermid-infested subalpine fir, *Abies lasiocarpa* (Hook.) Nutt. *Scymnus pumilio* (Wse.) was liberated in Pacific silver fir, *A. amabilis* (Dougl.) Forbes, and *Pullus impexus* Muls. in grand fir, *A. grandis* (Dougl.) Lind. Adults of *Exochomus uropygialis* Muls. were released in stands of all three tree species.

^{4/} See footnote ^{2/}, page 1.

Release Results

Results of the laboratory tests were not promising. It appeared that the insects received from India and Pakistan were univoltine, and that the year's life cycle had already been completed. After release, most of the predators completely ignored the aphids, fed awhile on sugar, and then became almost completely quiescent. Only E. uropygialis and Harmonia breiti fed on the prey; and their feeding lasted only for an hour or two immediately after release. No oviposition was observed and, except for two pairs of A. luteopicta, there was no mating.

Rapid mortality of Oenopia sauseti and Adalia tetraspilota began soon after release; otherwise, mortality in the cages during the first 3 to 4 weeks was slight. After a month, however, beetle mortality increased sharply in all cage populations. By early December, the only living insects were 17 A. luteopicta, 57 E. uropygialis, and 61 H. breiti. These specimens were prepared for winter storage at this time by placing them in excelsior-filled ice-cream containers, refrigerating them at 44° F. for one week, and then transferring them to 34° F. for the rest of the winter. If they survive the winter, these predators will be given another opportunity in the spring to feed and reproduce in the laboratory.

Indications of success were no more apparent in the field than in the laboratory. None of the predators were observed to produce progeny, and all but one species disappeared within two weeks after release. The most promising predator appeared to be Pullus impexus, which fed on the balsam woolly aphid after release and was present in the release area 2-1/2 months after liberation. However, no eggs could be found during an inspection made in February, 1961. Further checks on all species will be made in the spring of 1961.

STATUS OF PREDATORS RELEASED FROM 1957 THROUGH 1960

Predators introduced into the Pacific Northwest have shown varying degrees of success in adapting to the new environment. Some have survived several generations; one produced progeny and then disappeared. Many failed to survive even a few weeks after release. For the purpose of this report, the insects are divided into two groups. The first is discussed under "established predators"; the second under "other predators". An established predator is arbitrarily defined as one that: (1) has survived at least one winter in its new environment, and (2) produced progeny that successfully complete its life cycle by preying wholly or in part on the balsam woolly aphid.

Established Predators

The four introduced predators meeting the definition of establishment are a beetle, Laricobius erichsonii; and three flies, Aphidoletes thompsoni, Cremifania nigrocellulata, and Leucopis obscura. All are European imports (Table 2). Their principal host in Europe was the balsam woolly aphid, and they have continued to prey on that host in the Pacific Northwest. Their present status in this region is discussed below.

Laricobius erichsonii Rosen. (Coleoptera: Derodontidae) - Of the four established predators, L. erichsonii appears the most promising. It has survived two winters in the Pacific Northwest and has produced sizable populations in most liberation areas. Dispersal has been moderate and predation significant in most release areas. The insect's chief drawback is that it has only one generation per year. Most of the control benefits occur during a very short time in the spring.

In 1958 and 1959, some 10,000 L. erichsonii were released in 8 localities in Oregon and Washington (Table 4 and Fig. 1, Appendix). There was only one failure and two near failures, all in the Willamette Valley in Oregon--no predator recoveries were made at Corvallis, and populations were extremely small at Long Tom River and Monroe. The reason for the lack of success in Willamette Valley liberations is not known precisely, although it appears that summer soil conditions may be responsible. Large larval populations were noted immediately after each release; but, by the time the larvae had matured and were ready to drop to the soil for pupation, the ground had become extremely hard and dry. In contrast, the soils in the higher elevation release areas were loose and moist throughout most of the year. In those localities, establishment and survival was uniformly good.

Dispersal distance of L. erichsonii was studied in each area where the predator was established. Random observations were made in 1959, and transects radiating from the point of release were run in 1960. Maximum observed dispersal two years after release was 850 feet, at Willamette Pass, Oregon. The next greatest spread after two years was 450 feet, at Green River, Washington. Laricobius was found preying on C. piceae populations on most of the infested trees within the zones of spread. Generally, the trees without predator populations were those with very light aphid infestations. L. erichsonii larvae were never found on trees where the prey density averaged less than 5.75 aphids per square inch of bark surface.

Table 2.--Foreign insect predators introduced since 1957 for control of the balsam woolly aphid in Oregon and Washington

| Species and family | Source | Number released by years | | | | Total |
|--|-------------------------------|--------------------------|--------|--------|--------------------|--------|
| | | 1957 | 1958 | 1959 | 1960 ^{1/} | |
| <i>Aphidoletes thompsoni</i> (Diptera: Itonididae) | Czechoslovakia and Germany | 1,830 | 2,480 | 29,894 | | 34,204 |
| <i>Laricobius erichsonii</i> (Coleoptera: Derodontidae) | Czechoslovakia and Germany | | 8,525 | 1,600 | | 10,125 |
| <i>Leucopis obscura</i> (Diptera: Chamaemyiidae) | Maine (Europe) | | 700 | 2,085 | | 2,785 |
| <i>Aphidecta oblitterata</i> (Coleoptera: Coccinellidae) | Sweden, Germany | | 720 | 718 | | 1,438 |
| <i>Cremifania nigrocellulata</i> (Diptera: Chamaemyiidae) | Czechoslovakia and Germany | | 385 | 989 | | 1,374 |
| <i>Chilocorus kuwanae</i> (Coleoptera: Coccinellidae) | Japan | | 135 | | | 135 |
| <i>Scymnus pumilio</i> (Coleoptera: Coccinellidae) | Australia | | | 859 | 2,000 | 2,859 |
| <i>Exochomus uropygialis</i> (Coleoptera: Coccinellidae) | Pakistan | | | 1,957 | 4,725 | 6,682 |
| <i>Synharmonia conglobata</i> (Coleoptera: Coccinellidae) | India | | | 121 | 6 | 127 |
| <i>Adalia tetraspilota</i> var. <i>bispilota</i> (Coleoptera: Coccinellidae) | India | | | 89 | 12 | 101 |
| <i>Ballia eucharis</i> (Coleoptera: Coccinellidae) | Pakistan | | | 85 | | 85 |
| <i>Leis dimidiata</i> (Coleoptera: Coccinellidae) | India | | | 23 | | 23 |
| <i>Leucopis</i> sp. (Diptera: Chamaemyiidae) | Pakistan | | | 15 | | 15 |
| <i>Harmonia breiti</i> (Coleoptera: Coccinellidae) | India | | | 10 | 73 | 83 |
| <i>Pullus impexus</i> (Coleoptera: Coccinellidae) | Germany | | | | 400 | 400 |
| <i>Adalia luteopicta</i> (Coleoptera: Coccinellidae) | India | | | | 156 | 156 |
| <i>Oenopia sauseti</i> (Coleoptera: Coccinellidae) | India | | | | 46 | 46 |
| <i>Exochomus uropygialis</i> var. <i>lituratus</i> (Coleoptera: Coccinellidae) | Pakistan | | | | 43 | 43 |
| Totals | | 1,830 | 12,945 | 38,445 | 7,461 | 60,681 |

^{1/} 1960 releases corrected for mortality.

During 1960 dispersal studies at Willamette Pass, L. erichsonii larvae and adults were observed preying on an unknown species of Pineus infesting Engelmann spruce, Picea engelmanni (Parry) Engelm. The significance of this finding is not yet known. An additional host could be either helpful or detrimental to the biological control effort--helpful by aiding dispersal and maintaining predator populations when the balsam woolly aphid is scarce, or detrimental by diverting predators from the intended host.

The effectiveness of L. erichsonii as a control agent has been studied for two years. Results to date have shown that the beetle is an effective predator when it is caged on a single chermid-infested stem, or released where only a few infested stems are present. This was demonstrated in 1959 when some 800 beetles provided a high degree of control when caged on a single aphid-infested tree at Monroe, Oregon, and in 1960 when excellent control was provided at Wind River, Washington, where only three Chermes-infested trees were present.

When a large number of aphid-infested trees were available for predation, L. erichsonii was not effective. In 1960, effectiveness studies at Willamette Pass and Black Rock, Oregon, revealed that epidemic aphid populations were significantly reduced by the predator but that the trend for the year continued upward. L. erichsonii reduced the rate of C. piceae population increase by about 50 percent but was not controlling the epidemic. It is hoped that effectiveness will improve as predator populations increase and are more widely distributed. Studies will be continued to see if such a pattern appears.

For detailed information on biology and effectiveness of Laricobius erichsonii in the Pacific Northwest, reference is made to a paper now being prepared for formal publication. 5/

In 1960, larvae of a native Laricobius species were collected at Corvallis, Oregon, and at Hoyt Arboretum in Portland. The predators were taken from a western hemlock, Tsuga heterophylla (Rafn.) Sarg., heavily infested with C. tsugae (Annand) at Corvallis and on Abies koreana Wils. infested with C. piceae at Hoyt Arboretum. Adults were not collected at either area even though frequent visits were made until the last of September.

5/ Buffam, P. E. 1961. Observations on the Effectiveness and Biology of the European predator Laricobius erichsonii Rosen. (Coleoptera: Derodontidae) in Oregon and Washington. (Probably published in The Canadian Entomologist).

In March and April, 1961, adults of a species very similar to L. nigrinus Fend. were collected at Corvallis on the C. tsugae-infested tree and on western white pine, Pinus monticola Dougl., infested with an unknown species of Pineus. A few weeks later, the same species was collected at Hoyt Arboretum from mountain hemlock, Tsuga mertensiana (Bong.) Carr., and western hemlock infested with C. tsugae, and from the Korean fir infested with C. piceae. Adults were sent to the describer of L. nigrinus, Mr. K. M. Fender of McMinnville, Oregon. He identified the predator as superficially similar to L. nigrinus but undoubtedly a different species, probably undescribed. Lateral lobes of the aedeagus were observed as being nearer those of L. laticollis Fall. than those of L. nigrinus.

Aphidoletes thompsoni Mohn. (Diptera: Itonididae) - This tiny fly was the first predator of Chermes piceae introduced into the Pacific Northwest. In three years, from 1957 to 1959, more than 34,000 Aphidoletes adults were reared for release in 8 different locations in Oregon and Washington (Table 4, Fig. 1, Appendix). Establishment was obtained at four of the localities: Green River in Washington, and Black Rock, Monroe, and Willamette Pass in Oregon. A. thompsoni has not been recovered at Corvallis or McKenzie Pass in Oregon, or at Randle or Coldwater Creek in Washington. However, visits to some areas were too few in 1960 to judge accurately whether colonization had failed. Larvae were collected shortly after release at Randle, Washington, and McKenzie Pass, Oregon, in 1959, but predator populations failed to reappear the next spring.

A rearing experiment in 1959 showed that A. thompsoni can be propagated in cages in the laboratory, transferred to the field in the larval stage, and successfully colonized. 6/

A. thompsoni should be one of the best balsam woolly aphid predators because fecundity is high, the insect is multi-voltine, and it can survive at relatively light prey densities. In 1958 and 1959, it appeared that Aphidoletes would live up to expectations because populations were quite large. During both summers, larvae were recovered from early July to late September at high elevations and from early May to late July at Monroe, a low elevation area; dispersal was fair, and predation appeared significant. In 1960, however, Aphidoletes populations were noticeably smaller at all establishment points. Also, the period of larval recovery was much shorter than it was in previous years; no Aphidoletes were recovered after July 25. The reason for the sudden drop in predator numbers is unknown.

6/ See footnote 3/, page 1.

Cremifania nigrocellulata Cz. (Diptera: Chamaemyiidae) - Adults of this fly were released at three Oregon localities in 1958 and 1959: Corvallis, Monroe, and Willamette Pass (Table 4 and Fig. 1, Appendix). Only the 1958 colony at Willamette Pass failed to become established. In 1960, larvae were found at Corvallis from May 24 to September 14. At Monroe, larvae were present from May 24 to September 13 and puparia from April 6 to June 9. Larvae were never seen in great numbers on the trees, and reduction of the C. piceae population was not noticeable.

Some predator collections from Pineus sp. have suggested that a sibling species of C. nigrocellulata may be native to the Pacific Northwest. In 1959, a chamaemyiid was collected feeding on an unknown species of Pineus infesting western white pine, Pinus monticola Doug., at Corvallis. This predator was identified by Sabrosky of the U. S. National Museum and McAlpine of the Canadian Entomology Research Institute, as Cremifania nigrocellulata. Because the Pineus predators were collected only two months after release of the foreign shipment, and at least a mile from the liberation point, it is possible that the predator on Pineus is a native insect. The possibility of a sibling species is further suggested by a 1958 collection of Cremifania larvae preying on Pineus at Centralia, Washington--some 200 miles from the nearest C. nigrocellulata release area. Adults were not reared from the Centralia infestation in 1958 but efforts will be made to secure specimens in 1961.

Leucopis obscura (Hal.) (Diptera: Chamaemyiidae) - L. obscura appears well-established at the two 1959 release areas at Willamette Pass, but progeny were never recovered from the 1958 liberation at Green River, Washington. Observations in 1960 at Willamette Pass revealed Leucopis larvae on trees from July 19 through November 10; puparia were collected from July 19 to September 12 and again from October 25 through the last observation on November 10. Dispersal was not investigated systematically, but immature stages were recovered on trees 200 to 300 feet from the original release point.

Control delivered by this species has not been assessed, but it may be significant. At one time during the summer of 1960 the density of L. obscura on an infested tree averaged 16.5 larvae and puparia per 1000 square inches of bark surface. L. obscura may prove to be especially effective in late summer and early fall. So far, the fall generation of the balsam woolly aphid in the Pacific Northwest has been subjected to very little predation.

Other Predators

This section discusses the 14 species of introduced predators that have not yet satisfied the previously mentioned criteria for establishment. Most of them are of Asian origin, and their original prey was some chermid other than the balsam woolly aphid. A few species preyed on C. piceae after their release and may become established. In most cases, however, it is too early to predict with any certainty which predators, if any, succeed. Establishment checks should be made for at least 5 years following release. Table 4 and Fig. 1 in the Appendix present details concerning the time and locations of releases.

Adalia luteopicta Muls. (Coleoptera: Coccinellidae) - This coccinellid was received for the first time in 1960. Four shipments, totaling 156 specimens, were liberated in a laboratory cage. Twenty adults of the first shipment were subsequently field-released in Hoyt Arboretum in Portland. Adults liberated in the Arboretum could not be found two weeks after release, and no progeny were recovered later. Results of cage studies were reported in the section on 1960 release results.

Adalia tetraspilota Hope var. bispilota Wse. (Coleoptera: Coccinellidae) - This predator was released in Oregon at Monmouth, Portland, and Santiam Pass in 1959, and in the laboratory in 1960. There were no recoveries from the 1959 liberations. The 12 beetles released July 27, 1960, in the laboratory cage died by the middle of August. No feeding, mating, or oviposition was observed.

Aphidecta oblitterata L. (Coleoptera: Coccinellidae) - More than 1400 adults of this European predator were released at Green River and Wind River, Washington, and at Corvallis, Oregon, in 1958 and 1959. No progeny were recovered from the 1958 liberations; however, a sizable larval population appeared at Wind River soon after the 1959 release. Mating adults were also observed that fall, but the predator failed to appear in 1960. Brown and Clark ^{7/} noted a similar situation in New Brunswick and concluded that the predators probably could not survive the cold winters. This may also be the case at Wind River, although it seems unlikely that the climate there would be significantly more severe than that in Germany, the source of the beetles. It has been speculated that the predator may have changed hosts and left the release area.

^{7/} Brown, N. R. and R. C. Clark. 1959. Studies of predators of the balsam woolly aphid, Adelges piceae (Ratz.) (Homoptera: Adelgidae). VI. Aphidecta oblitterata (L.) (Coleoptera: Coccinellidae), an introduced predator in eastern Canada. Can. Ent., 91(9):596-99.

Ballia eucharis Muls. (Coleoptera: Coccinellidae) - Eighty-five Ballia adults were released at Black Rock in the fall of 1959, but no recoveries were made then or in 1960.

Chilocorus kuwanae Silv. (Coleoptera: Coccinellidae) - In 1958, some 130 adults of this predator, which feeds on Chermes todomatsui Inouye in Japan, were field-released at Monroe, Oregon, and Coldwater Creek, Washington. No recoveries have been made. A laboratory release the same year was also unsuccessful. Presumably, the climate or host here were unsuitable.

Exochomus uropygialis Muls. (Coleoptera: Coccinellidae) - In 1959 and 1960, more than 6,000 E. uropygialis adults were field-released in Oregon and Washington. Release locations were Corvallis and Santiam Pass in Oregon and Green River and Toutle Lake in Washington. In addition, 300 of the predators were confined in a rearing cage at the Sellwood laboratory in Portland.

At first appearance, E. uropygialis seemed to be the most promising of the Asian imports. The beetles started feeding on the balsam woolly aphid immediately after liberation, there was a minimum of aimless flying, and no apparent attempt was made at mass dispersal into the upper branches of the release trees, as with some species. Although neither mating nor oviposition was observed, the predator seemed well adjusted to its new chermid host. However, no evidence of the beetle was found during several examinations made from 2 weeks to 15 months after liberation. Laboratory observations on the confined predator population suggest that the beetles introduced in both years selected a hiding place and went into hibernation within a few days after release. Progeny of the beetles released in 1959 could not be found in 1960. Searching will be continued at all areas in 1961.

Exochomus uropygialis var. lituratus Gorb. (Coleoptera: Coccinellidae) - This predator was released in the Pacific Northwest for the first time in 1960. On August 5, 43 adults were liberated at Santiam Pass along with 2400 specimens of E. uropygialis. Some of the beetles began feeding on C. piceae immediately after release. Only one or two specimens were found on the release tree a week later; none were found thereafter.

Harmonia breiti Mader (Coleoptera: Coccinellidae) - In 1959, ten Harmonia adults were released at Hoyt Arboretum in Portland, and in 1960 a shipment of 73 beetles was released in a rearing cage in the laboratory. The results of the laboratory study were discussed in a previous section. The 1959 field release apparently failed.

Leis dimidiata F. (Coleoptera: Coccinellidae) - A total of 23 adult L. dimidiata was released at Monmouth and Willamette Pass, Oregon, in 1959. No stages of the predator were seen in 1960, when prey populations on both release trees were either light or lacking. However, enough host material was available in the immediate vicinity to support a predator population. Because the number of specimens released was very small and no progeny have been recovered, it appears that L. dimidiata perished.

Leucopis (Neoleucopis) sp. (Diptera: Chamaemyiidae) - In 1959, 15 specimens of this Pakistanian import were released at Monroe, Oregon. Progeny were never recovered. Apparently this species did not survive in its new environment.

Oenopia sauseti Muls. (Coleoptera: Coccinellidae) - This Indian coccinellid was received in the Pacific Northwest for the first time in 1960. Twenty-five adults were released in a cage at the laboratory on August 11, and another 21 were caged on August 25. None of the beetles were seen feeding on C. piceae, but some fed on sugar when it was placed in the cage. The attempt at cage rearing was discontinued on September 26. By then only one beetle was alive. Failure of the colony apparently was due to unsuitability of the host or unfavorable environment.

Pullus impexus Muls. (Coleoptera: Coccinellidae) - Pullus, an important predator of the balsam woolly aphid in Europe, was released for the first time in the Pacific Northwest on June 18, 1960. Four hundred adults were liberated in a small grand fir woodlot at Long Tom River, Oregon. Some of the beetles began feeding on the C. piceae immediately after release, but most appeared sluggish and remained in the shipping box. Small numbers of adults were seen on the bark of the release tree until September 1, but no eggs or larvae were observed. A close check of this area will be made in 1961 to assess the success of this species in becoming established.

Scymnus pumilio (Wse.) (Coleoptera: Coccinellidae) - A total of about 2800 of these Australian predators were released in 1959 at Coldwater Creek, Washington, and in 1960 at Green River, also in Washington. In both years, the predators disappeared very shortly after liberation and were not seen again. The 1959 host tree at Coldwater Creek formed secondary periderm shortly after the predators were released, killing the aphid population; however, host material was abundant on surrounding trees. It may be that the species had difficulty in adapting to the reversed seasons in the Northern Hemisphere.

Synharmonia (Coccinella) conglobata L. (Coleoptera: Coccinellidae) -
Two shipments totaling 121 Synharmonia adults were field-released in 1959 at Santiam Pass, Oregon, and Randle, Washington. In 1960, six beetles were released in a laboratory cage. Observations in 1960 failed to detect the insect at either field release location. Predators in the laboratory did not feed, and they died within a month. Results of the laboratory test and field liberations suggest that S. conglobata will not survive and reproduce on C. piceae.

PROJECT PERSONNEL

Entomologist K. H. Wright, of the Division of Forest Insect Research of the Pacific Northwest Forest and Range Experiment Station, was responsible for the overall direction of the introduction and colonization project. Entomologist R. G. Mitchell was directly responsible for detailed planning of all studies and for technical guidance of the predator introduction and assessment program. The immediate responsibility for conducting the work on colonization and assessment of foreign predators was assigned to entomologist P. E. Buffam. Buffam and forestry aid J. N. Owens conducted the field work and aided Mitchell in the laboratory work. Biological aid J. C. Neeley assisted in making field forms, mounting insects, and maintaining rearings whenever necessary. N. E. Johnson, entomologist of Weyerhaeuser Company, Centralia, Washington, supplied technical information and assisted in some of the liberations.

APPENDIX

Table 3.--Shipments and colonizations of foreign predators of the balsam woolly aphid in 1960

| Species | Source | Shipment no. and no. of predators | Shipment date, place and carrier | Arrival date in : on : Portland: | Condition : on : arrival | Date : of : release | Location : of : release | No. re-leased | Temper-ature | Type : of : release | Host pop. : on : release tree | Species : of : release tree | Released by |
|--|-----------|-----------------------------------|--------------------------------------|----------------------------------|--------------------------|---------------------|-------------------------------------|---------------|---------------|---------------------|-------------------------------|--------------------------------------|-------------------------------------|
| <i>Adalia luteopicta</i> Muls. | India | 1 - 27 | 7/19 - Moorestown, N.J.--Air Mail | 7/19 | Good-1 dead | 7/19 7/28 | Sellwood lab. Portland, Ore. | 6 20 | 70° F. 83° F. | Cage Free | Heavy | <i>Abies lasiocarpa</i> | Staff Mitchell |
| | | 2 - 36 | 8/11 - do. | 8/12 | Good-1 dead | 8/12 | Sellwood lab. | 35 | 70° F. | Cage | - | - | Mitchell, Buffam |
| | | 3 - 36 | 9/8 - do. | 9/9 | Very good--no mort. | 9/10 | Sellwood lab. | 36 | 70° F. | Cage | - | - | Mitchell |
| | | 4 - 60 | 9/13 - do. | 9/14 | Good-1 dead | 9/14 | Sellwood lab. | 59 | 70° F. | Cage | - | - | Owens, Buffam |
| Subtotals | | 159 | | | | | | 156 | | | | | |
| <i>Adalia tetraspilota</i> Hope var. <i>bispilota</i> Wse. | India | 1 - 15 | 7/26 - do. | 7/27 | Fair-3 dead | 7/28 | Sellwood lab. | 12 | 70° F. | Cage | - | - | Mitchell, Owens |
| Subtotals | | 15 | | | | | | 12 | | | | | |
| <i>Exochomus uropygialis</i> var. <i>lituratus</i> Corh. | Pakistan | 1 - 44 | 8/1 - do. | 8/3 | Good-1 dead | 8/5 | Santiam Pass, Ore. | 43 | 72° F. | Free | Heavy | <i>A. lasiocarpa</i> | Buffam |
| Subtotals | | 44 | | | | | | 43 | | | | | |
| <i>Exochomus uropygialis</i> Muls. | Pakistan | 1-2400 | 8/1 - do. | 8/3 | Very good | 8/5 | Santiam Pass, Ore. | 2400 | 72° F. | Free | Heavy | <i>A. lasiocarpa</i> | Buffam |
| | | 2 -900 | 8/1 - do. | 8/3 | Very good | 8/5 | (a) Green R., Wn. (b) Sellwood lab. | 600 300 | 68° F. 70° F. | Free Cage | Heavy - | <i>A. amabilis</i> | Johnson, Mitchell Owens |
| | | 3-1425 | 8/2 - do. | 8/3 | Very good | 8/5 | (a) Toutle L. Wn. (b) Green R. Wn. | 925 500 | 80° F. 68° F. | Free Free | Heavy Heavy | <i>A. grandis</i> <i>A. amabilis</i> | Johnson, Mitchell Johnson, Mitchell |
| Subtotals | | 4725 | | | | | | 4725 | | | | | |
| <i>Harmonia breiti</i> Mader | Pakistan | 1 - 73 | 11/1 - do. | 11/2 | Very good--no mort. | 11/2 | Sellwood lab. | 73 | 70° F. | Cage | - | - | Mitchell, Buffam |
| Subtotals | | 73 | | | | | | 73 | | | | | |
| <i>Oenopia sauseti</i> Muls. | India | 1 - 25 | 8/9 - do. | 8/10 | Very good | 8/11 | Sellwood lab. | 25 | 70° F. | Cage | - | - | Staff |
| | | 2 - 23 | 8/23 - do. | 8/24 | Good-2 dead | 8/25 | Sellwood lab. | 21 | 70° F. | Cage | - | - | Buffam |
| Subtotals | | 48 | | | | | | 46 | | | | | |
| <i>Pullus impexus</i> Muls. | Germany | 1 -400 | 6/15 - Belleville, Ont.--Air Express | 6/17 | Good--Est. 10% mort. | 6/18 | Long Tom R., Ore. | 400 | 70° F. | Free | Heavy | <i>A. grandis</i> | Buffam |
| Subtotals | | 400 | | | | | | 400 | | | | | |
| <i>Scymnus pumilio</i> (Wse.) | Australia | 1-2000 | 5/31 - do. | 6/2 | Good--Est. 5-10% mort. | 6/3 | Green R., Wn. | 2000 | 75 F. | Free | Med.-heavy | <i>A. amabilis</i> | Buffam |
| Subtotals | | 2000 | | | | | | 2000 | | | | | |
| <i>Synharmonia</i> (Coccinella) <i>conglobata</i> L. | India | 1 - 9 | 9/6 - Moorestown, N.J.--Air Mail | 9/7 | Fair-3 dead | 9/10 | Sellwood lab. | 6 | 70 F. | Cage | - | - | Mitchell |
| Subtotals | | 9 | | | | | | 6 | | | | | |
| Totals | | 7473 | | | | | | 7461 | | | | | |

Table 4--Releases of foreign predators of the balsam woolly aphid
in Oregon and Washington from 1957 through 1960 by species.

| Species released | Source | Year of release | Number released: (adults) | Release area |
|---|-------------------------------|-----------------|------------------------------|-----------------------|
| <i>Adalia luteopicta</i> | India | 1960 | 136 | Sellwood Lab., Ore. |
| | " | 1960 | 20 | Portland, Ore. |
| <i>Adalia tetraspilota</i> | India | 1959 | 14 | Monmouth, Ore. |
| var. <i>bispilota</i> | " | 1959 | 54 | Portland, Ore. |
| | " | 1959 | 21 | Santiam Pass, Ore. |
| | " | 1960 | 12 | Sellwood Lab., Ore. |
| <i>Aphidecta oblitterata</i> | Sweden | 1958 | 395 | Corvallis, Ore. |
| | " | 1958 | 325 | Green River, Wn. |
| | Germany | 1959 | 718 | Wind River, Wn. |
| <i>Aphidoletes thompsoni</i> | Czechoslovakia | 1957 | 1,025 | Black Rock, Ore. |
| | " | 1957 | 368 | Green River, Wn. 1/ |
| | " | 1957 | 237 | Coldwater Cr., Wn. 1/ |
| | " | 1957 | 200 | Corvallis, Ore. |
| | " | 1958 | 2,480 | Monroe, Ore. |
| | Germany | 1959 | 10,495 | Black Rock, Ore. |
| | " | 1959 | 3,323 | Coldwater Cr., Wn. |
| | " | 1959 | 3,850 | McKenzie Pass, Ore. |
| | " | 1959 | 157 | Monroe, Ore. |
| | " | 1959 | 2,062 | Randle, Wn. |
| | " | 1959 | 845 | Sellwood Lab., Ore. |
| | Czechoslovakia and Germany | 1959 | 9,162 | Willamette Pass, Ore. |
| <i>Ballia eucharis</i> | Pakistan | 1959 | 85 | Black Rock, Ore. |
| <i>Chilocorus kuwanae</i> | Japan | 1958 | 55 | Monroe, Ore. |
| | " | 1958 | 80 | Coldwater Cr., Wn. |
| <i>Cremifania nigrocellulata</i> | Czechoslovakia | 1958 | 385 | Willamette Pass, Ore. |
| | Germany | 1959 | 159 | Corvallis, Ore. |
| | " | 1959 | 830 | Monroe, Ore. |
| <i>Exochomus uropygialis</i> | Pakistan | 1959 | 316 | Corvallis, Ore. |
| | " | 1959 | 1,641 | Green River, Wn. |
| | " | 1960 | 1,100 | Green River, Wn. |
| | " | 1960 | 2,400 | Santiam Pass, Ore. |
| | " | 1960 | 300 | Sellwood Lab., Ore. |
| | " | 1960 | 925 | Toutle Lake, Wn. |
| <i>Exochomus uropygialis</i> var. <i>lituratus</i> | Pakistan | 1960 | 43 | Santiam Pass, Ore. |
| <i>Harmonia breiti</i> | India | 1959 | 10 | Portland, Ore. |
| | Pakistan | 1960 | 73 | Sellwood Lab., Ore. |
| <i>Laricobius erichsonii</i> | Czechoslovakia | 1958 | 1,550 | Black Rock, Ore. |
| | " | 1958 | 1,705 | Corvallis, Ore. |
| | " | 1958 | 1,200 | Willamette Pass, Ore. |
| | " | 1958 | 1,320 | Coldwater Cr., Wn. |
| | " | 1958 | 1,600 | Green River, Wn. |
| | " | 1958 | 1,150 | Wind River, Wn. |
| | Germany | 1959 | 800 | Long Tom River, Ore. |
| | " | 1959 | 800 | Monroe, Ore. |
| <i>Leis dimidiata</i> | India | 1959 | 8 | Monmouth, Ore. |
| | " | 1959 | 15 | Willamette Pass, Ore. |
| <i>Leucopis obscura</i> | Maine | 1958 | 700 | Green River, Wn. |
| | " | 1959 | 2,085 | Willamette Pass, Ore. |
| <i>Leucopis</i> sp. | Pakistan | 1959 | 15 | Monroe, Ore. |
| <i>Oenopia sauseti</i> | India | 1960 | 46 | Sellwood Lab., Ore. |
| <i>Pullus impexus</i> | Germany | 1960 | 400 | Long Tom River, Ore. |
| <i>Scymnus pumilio</i> | Australia | 1959 | 859 | Coldwater Cr., Wn. |
| | " | 1960 | 2,000 | Green River, Wn. |
| <i>Synharmonia (Coccinella)</i> | India | 1959 | 30 | Santiam Pass, Ore. |
| conglobata | " | 1959 | 91 | Randle, Wn. |
| | " | 1960 | 6 | Sellwood Lab., Ore. |

1/ Release area reported as Toutle River, Wn., in 1957, 1958, and 1959.

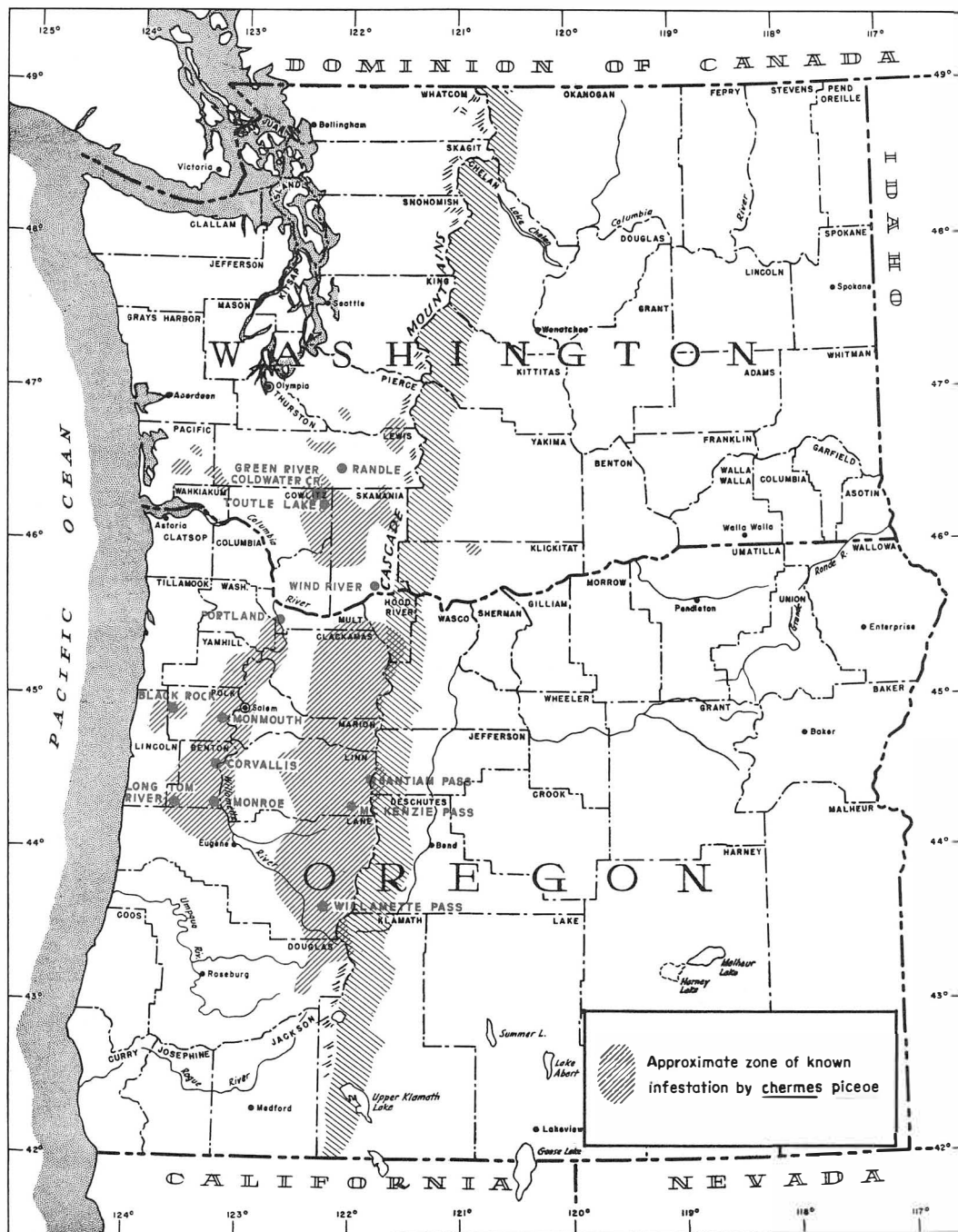


Figure 1.--Location of release areas in Oregon and Washington used for liberating foreign predators of the balsam woolly aphid from 1957 through 1960.